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NEW HAMPSHIRE
AGRICULTURAL EXPERIMENT STATION

DEPARTMENT OF ENTOMOLOGY

The Codling Moth

AND

How to Control It by Spraying

The Codling Moth—Enlarged

By E. DWIGHT SANDERSON

NEW HAMPSHIRE COLLEGE
OF
AGRICULTURE AND MECHANIC ARTS
DURHAM, N. H.

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THE CODLING MOTH.

BY E. DWIGHT SANDERSON.

Introduction. Bulletin 131 of this Station, issued in April, 1907, discussed "Spraying the Apple Orchard" both as regards insects and diseases, and was based upon our investigations in 1905 and 1906. Investigations of the codling moth were continued in 1907 and 1908 and have been described in detail in the Nineteenth and Twentieth Reports. The present bulletin will give the practical results of these studies in popular form.

The Codling Moth is our principal insect pest of apples. The fruit is also seriously injured by the apple maggot or "railroad worm," but usually it injures only summer and fall varieties and is not so generally injurious. However, during the past season apples of nearly all varieties have been "railroaded" and we are now making a thorough investigation of the insect, and after a few years of orchard experiments we hope to be able to advise how it may be practically controlled. The maggot should never be confused with the codling moth, as they are totally dissimilar in appearance and habits. Spraying is of no value for the maggot so far as now known.

Fig. 1.—The work of the Apple Maggot.

The plum curculio also injures the fruit by laying its eggs in the young apples. Usually these drop while small and a footless white grub, looking much like the larva of the codling moth, develops in them. Where the apples remain on the tree the egg scars cause a pitting and gnarling of the fruit, often rendering it very inferior and unsalable, especially with summer varieties. The work of the curculio may be recognized by the crescent-shaped or semi-circular brown scar left on the apple. The spray-

ing given for the codling moth aids in the control of the plum curculio, as will keeping the drops picked up and cultivating the orchard.

The aggregate annual loss to New Hampshire fruit growers through the work of the codling moth is hardly appreciated, as most of the wormy fruit drops and is not observed, but careful

Fig. 2.—Apples scarred by the Plum Curculio.

observations both by this Station and by fruit growers show a loss of fully one-third the total crop, which would be equivalent to an annual cash loss of at least one-quarter of a million dollars.

I. LIFE HISTORY.

Successful control of a pest of so great economic importance must be based upon a thorough knowledge of its habits, and exhaustive studies of every phase of the life of the insect have therefore been made during four years.

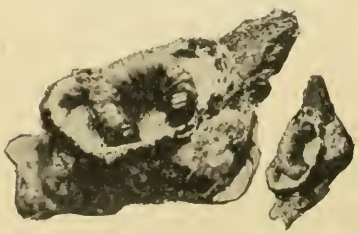
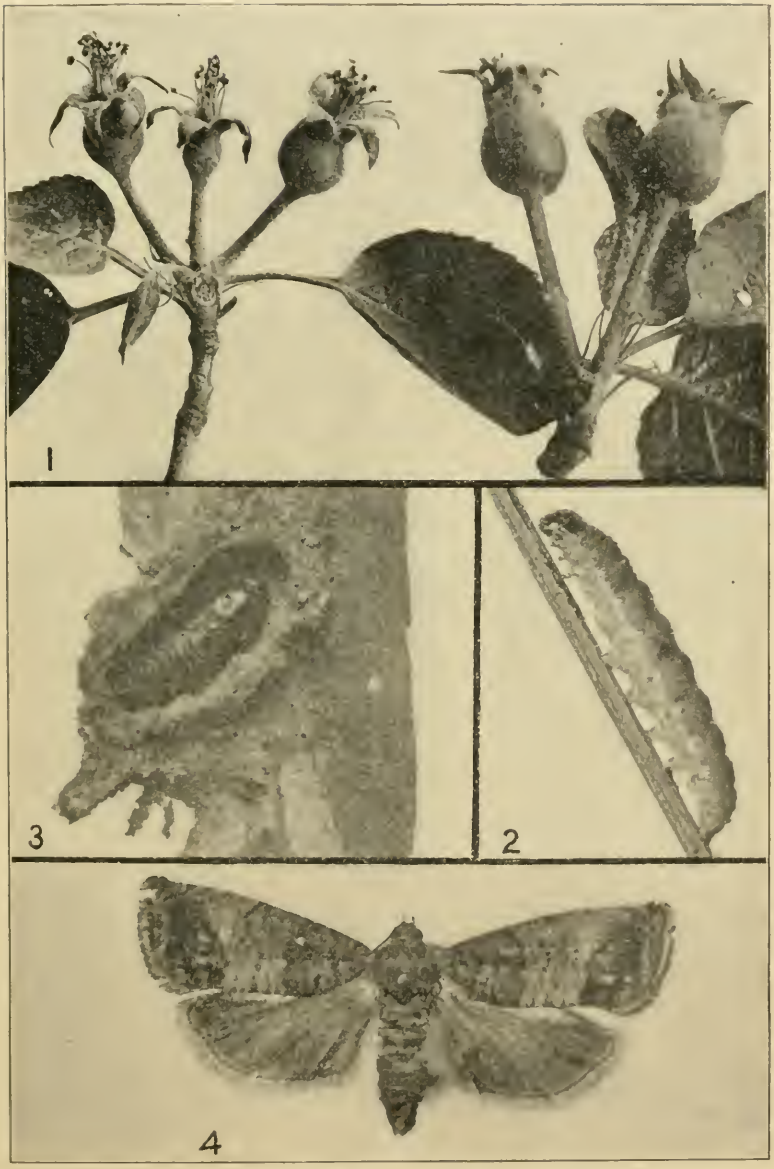


Fig. 3.—The apple worm in its winter home, the cocoon under a bit of bark.

How the Winter Is Passed. Examine the bit of apple bark on which a woodpecker has been picking and you will doubtless find that a clean hole has been drilled through it and directly into a small, white cocoon, now empty, for no one knows the winter home of the codling moth so well as its worst enemy, the woodpecker. Usually the apple worm forms its cocoon under the



THE CODLING MOTH AND ITS CORTNOL.

Fig. 4: 1.—Young apples, showing, on left, the calyx lobes open, and in right condition for first spraying; on right, calyx lobes closed, and almost, if not quite, too late for spraying. 2.—The codling moth larva, or apple worm. 3—Codling moth pupa, in its cocoon, under scale of bark from trunk of apple tree. 4.—Codling moth or parent of apple worm. Figures 2, 3, and 4 enlarged about three times. (After Quaintance, U. S. Dept. Agr.)

bark or in the crevices of the trunk, but often cocoons are made under boards, or in an apple barrel or bin. In a careful examination of seven trees it was found that 70 per cent. of the cocoons are on the trunk and that the remainder are found on some of the larger and rougher limbs at an average distance of about 3 feet from the crotch. More of the cocoons are on the lower than on the upper part of the trunk, as when the caterpillars leave the dropped apples they crawl up the trunk and make their cocoons at the first suitable points.

Only from 5 to 20 per cent. of the larvæ survive the winter. An examination of seven trees, which averaged 38 cocoons per tree in the fall, showed but 5 per cent. alive in the spring, 87 per cent. having been killed by birds, 4 per cent. by disease and 3 per cent. by cold. In another orchard 1,096 cocoons were examined in May, 1907, with 19 per cent. alive, 66 per cent. having been killed by birds, 6 per cent. by disease and 9 per cent. by cold. It is quite evident that the birds, particularly the downy woodpeckers and the nuthatches are the most important enemies of the codling moth in New England and that they should be given every protection and be attracted to the orchard in every way possible.

The Transformation. During May or early June, the caterpillar opens the end of the cocoon and spins a silken tube from it to the surface. Then retiring to the cocoon, with its head towards the opening, it sheds its winter clothes, transforming into a pupa. The pupa is a dormant stage in which the insect has almost no power of motion, and shows but little sign of life, but during which wonderful changes in its structure are going on, so that from the old tissues of the worm-like larva are formed the organs of the active, winged moth. In 1906 pupation commenced May 7, the last larva did not pupate until early in June, but the average date was May 25. In June, 1907, the average date of pupation was June 16 or three weeks later, while in 1908 the average date was June 1, the first pupa being on May 20 and the last June 9. The time of pupation is therefore seen to vary greatly with the season, but with average weather conditions to occur about June 1.

The time passed in the pupal stage also varies with the season and the time when the pupa is formed. Pupæ formed in

early May will require 25 to 30 days to transform to moths, while those formed the middle of June will require 11 to 15 days, the average for a large number for the whole season being about 16 days. At the end of this time the pupæ wriggles itself out of the cocoon through the silken tube made by the larva, its skin splits down the middle of the back and from out the pupal shell, crawls the adult moth, somewhat bedraggled, but soon ready for flight.

The time of appearance of the moths also varies, but as those pupæ first formed require longer to transform than those formed later, there is less variation in the time of appearance of the moths. In 1906 the majority of moths appeared June 14, in 1907 on July 2, and in 1908 on June 20, the latter date being probably the most usual. In 1908 the moths emerged from June 11 to July 7.

The Moth. The codling moth is rarely seen, for it flies at night and during the day it remains motionless on or under the bark which it so closely resembles as to be invisible. It is a beautiful little creature when closely examined. Its wings expand from three-fourths to one inch and when seen at a little distance have somewhat the appearance of grayish-brown watered silk, but when closely examined are seen to be crossed by numerous lines of gray and brown scales. Near the hind angle of each front wing there is a large dark brown spot marked with streaks of bronze or gold. The hind wings are of lighter grayish-brown color, darker toward the outer margin. The moths fly mostly during the early evening, and if the evenings be warm when they emerge the females commence to lay their eggs in two or three days, but if cool they may not oviposit for ten days or two weeks. Moths observed under normal conditions have lived three to four weeks, but most of them live but one to two weeks.

The Egg. The individual egg upon the leaf or fruit (see fig. 5) looks much like a small white blister, about the size of a pinhead. It is at first quite transparent, but later a blackish streak is seen, showing the caterpillar forming within. The eggs are seen with difficulty and are found only by the most careful search. An average of 60 to 75 eggs are deposited by different individuals for about a month. The egg-laying habits of the moths were studied with great care for two sea-

sons. Among other methods used for securing the exact knowledge concerning them, was that of erecting a large frame covered with cheese cloth over a ten-year-old apple tree and introducing in it a single pair of the codling moths. Before doing so every leaf on the tree was carefully examined to be sure that no eggs had already been laid. The leaves and fruit on the tree were then examined at frequent intervals, every fruit and leaf being examined and each egg marked with a tag as laid. This enabled us to determine exactly when and where the eggs were laid, how far they were from the nearest apples and other points, all of which have a practical bearing upon combating the pest, as will be seen below. Three of these large cages and numerous smaller ones covering individual limbs or twigs were used. It was found that practically all of the eggs were laid upon the leaves, upon the upper or under surface indiscriminately, and a few, less than two per cent., on the apples and bark. In three years 796 eggs were observed. Large numbers are laid on foliage of limbs not bearing fruit and often on trees with no fruit. The average distance of the egg from the fruit is nine inches, but there seems to be no direct relation between the distance of the eggs from the fruit and the resulting amount of worminess. Our observations indicate that there is a very large mortality of young larvæ from the time they leave the eggs until they enter apples.

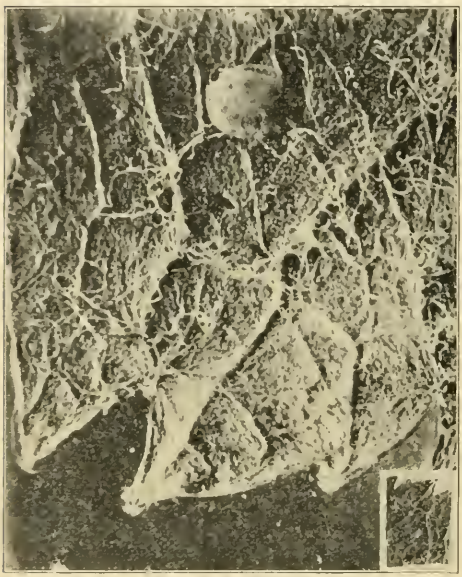


Fig. 5—Egg of codling moth on leaf—greatly enlarged and natural size.

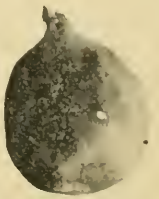


Fig. 6.—Codling moth egg on apple, about natural size.

Although there is a considerable variation in the time the eggs are laid, due to the time of emergence of the individual moths and the character of the season, three years' observations would indicate that most of them are laid about July 1. The eggs hatch in from five to ten days, depending upon when they were laid, the average time being about eight days. The time of hatching of the eggs in relation to the time of the apple blossoms dropping is most important in determining the time for the second spraying, as will be shown by the experiments described on page 74. In 1906 the first eggs hatched 21 days after the blossoms fell, in 1907 in 11 days, and in 1908 in 21 days, while the majority of the eggs hatched 26 days after the blossoms fell in 1906 and 30 days in 1907 and 1908. It is evident, therefore, that the majority of eggs do not hatch until about four weeks after the blossoms fall.

FIG. 7.— Young codling moth larva just hatched with egg shell—enlarged

The Larva, or Apple Worm. The young apple worm is at first only about one-sixteenth of an inch long, of a whitish color, with a shining black head, and with distinct, blackish tubercles on the back, which become quite obscure in later life. As soon as the young worm crawls from the eggs it usually makes a frugal breakfast upon the tender part of a leaf, preferably at the juncture of the veins on the under surface. Indeed, occasionally a worm may feed entirely upon the foliage and transform without entering an apple, as we have reared them upon tender water-sprouts. But this probably rarely occurs in the orchard, except, perhaps, when but little fruit is available. Very soon his appetite for green apples commences to assert itself, like that of the small boy, and he commences to search for young fruit. It was formerly supposed that most of the eggs were laid upon the apples, so that the young apple worm merely had to eat its way

in; but our observations show that many of the eggs are laid, three, four or five feet from the nearest apple. Indeed, a considerable proportion, sometimes a fifth to a third of the eggs, are laid upon limbs which bear no apples whatever. Of course,

Fig. 8.— The young apple worm feeding in the calyx cavity of the apple.

those so far from apples fail to reach the craved food, and doubtless most of them perish in the attempt, for we found there was an egg within about ten inches of nearly every wormy apple, whereas most of the worms which enter the apples probably come from eggs on the leaves clustering around the apple and the young worms do not have to crawl over four or five inches. Upon reaching the nearest apple about two-thirds of the worms enter them through the blossom end, feeding a little in the calyx to

appease their hunger after the long journey, and then boring directly for the core. This feeding in the blossom end is of the utmost importance in enabling us to destroy the young worm by spraying, as will be indicated later. The rest of the worms enter the fruit through the side, often where a leaf or another apple comes in contact. The seeds of the apple seem to be most relished by the apple worm, for it soon hollows out each of them as well as the surrounding core, its work being indicated by the well-known excreta thrown out of the calyx, showing the "worminess" of the apple. In from twenty-five to thirty days, having attained full growth, it eats its way out through the side of the apple, through which a round exit hole is left, and seeks a place

FIG. 9.—Showing the work of an apple worm which entered at the calyx and left through the side.

in which to form a cocoon. The full-grown apple worm is about three-fourths of an inch long, of a whitish or often pinkish color, and so well known as hardly to require further description.

About the last week in July the full grown larvæ commence to leave the apples and form their cocoons, and from that time until the apples are picked they continue to emerge, the larger number being formed about the first of September. The cocoons are formed under the bark, as already described, and there most of the larvæ pass the winter.

The Second Brood. A few of those larvæ which become grown by the last of July or the first week in August transform to pupæ the same as in the spring, and give rise to a partial second brood of moths. Only a part of the first matured larvæ

transform, and none have pupated after August 13. In 1907, on August 8, we secured 9 pupæ and 24 larvæ, three of which pupated before August 13. The moths emerged August 12 to 23, 1907. No larvæ were observed to transform after August 1, in 1908. From these and other observations it seems probable that one-third of the larvæ which form cocoons during the last week of July or first week in August transform to pupæ, but these would be not over 5 per cent. of the total larvæ of the first brood. These few moths lay their eggs probably in much the same manner as in early summer, although we have not been able to observe them, and doubtless more of the eggs are laid on

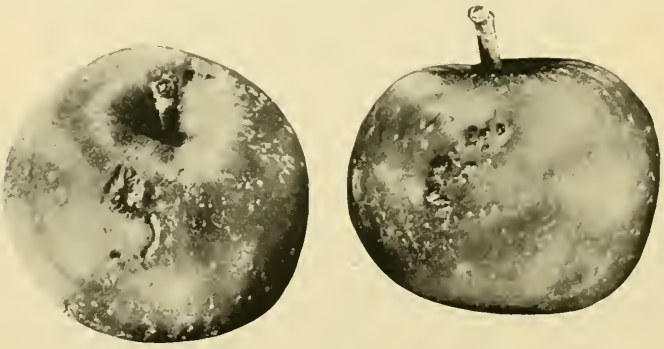


Fig. 10.—The little worms of the second brood fed upon or just under the surface.

the apples. The work of the young caterpillars of the second brood is noticeable after the middle of August. The feeding habits of these little worms of the second brood are quite different from the main summer brood, as they merely feed upon or just under the surface, often around or in the calyx, or where a leaf or another apple comes in contact with the skin, and rarely bore into the apple, as does the first brood. The difference in the food habits of this second brood has been observed by many growers and has led some to the belief that the work is that of a different insect. Although the Lesser Apple Worm (*Enarmonia prunivora*) occurs here commonly, it is by no means numerous enough to form any large part of the work attributed to the second brood of the codling moth. Although but less than five per cent., and probably only one or two per cent., of the larvæ transform to the second generation of moths, yet we find that

fully two-thirds of the picked fruit which shows the work of the codling moth has been affected by the second brood, which have marred the surface or eaten around the calyx, and only about one-third of those wormy show the characteristic work of the first brood. Indeed, the bulk of the apples attacked by the first brood fall to the ground as windfalls, and thus the damage done by it usually escapes notice. That so large a portion of the injury to picked fruit is due to the second generation of larvæ, when so small a percentage of the first generation transforms, seems rather remarkable. But if four larvæ in 100 of the first generation transformed to two pairs of moths they would lay enough eggs to produce as many larvæ as in the first generation, so that it is easily seen how the small percentage transforming can give rise to so much injury. Most of the larvæ of the second generation doubtless become full-grown, as young larvæ placed on apples September 5, 1906, were full grown and made cocoons on October 10. A number of half grown larvæ, possibly 20 per cent., are always found in cocoons in late fall or winter. These have always failed to transform the next spring, indicating that many of the larvæ of the second generation are overtaken by cold weather before becoming full grown.

II. EXPERIMENTS IN SPRAYING.

Experiments in spraying for the control of the codling moth were conducted in 1906, 1907 and 1908 to determine the following points:—

1. The relative value of different insecticides.
2. The amount of insecticide most profitable.
3. The best time or times to spray.
4. The best method of spraying.
5. How the spray kills the larvæ.
6. Effect of spraying on the proportion of dropped and picked fruits.

These experiments were carried on on a large scale and were so arranged that by comparison of the different plots definite conclusions could be drawn. They were located in ten different orchards at Durham, Greenland, Hancock, Walpole, Pittsfield

and Deerfield, in many of which the work was repeated the second year. Altogether over a million apples, on 521 trees, from 102 different plots were recorded. Every apple, which dropped after mid-July or which was picked was examined and recorded. Its condition as to worminess, whether the worms had entered the calyx or side of the apple, and whether it was injured by worms of the first or second brood was recorded. All the trees used in the experiments were Baldwins. Most of the plots were arranged so that blocks of at least fifteen trees were given similar treatment, and only the five central trees in the block were recorded, discarding the outside trees which might be affected by the neighboring plots. Therefore the total number of trees sprayed was nearly 1,500, though only 521 were recorded.

The detailed report of these experiments has been published and may be had upon application, but is of but little interest to the general reader. The conclusions drawn from the experiments are as follows:

1. **Value of Different Insecticides.** Arsenate of lead and Paris green are practically the only arsenical insecticides in general use against the codling moth. Where they are used alone the arsenate of lead is much superior to Paris green on account of its superior adhesiveness, not being washed off by rains as is Paris green, and because normal arsenate of lead never burns the foliage, as Paris green sometimes does. Where they are used with Bordeaux mixture, there is but little choice, as the Bordeaux sticks the Paris green to the foliage so that it adheres fully as well as arsenate of lead, though an occasional slight burning of the foliage results from Paris green.

2. **Amount of Insecticide.** Two pounds of arsenate of lead to 50 gallons of water gave very satisfactory results and was much superior to one pound. Where the work is thoroughly done two pounds per barrel are sufficient, but we believe three pounds per barrel, as usually recommended by the manufacturers, will be found profitable where spraying is done with a barrel pump with only average care. One-third of a pound of Paris green per barrel was found to be as effective, as far as killing the codling moth is concerned, as two pounds of arsenate of lead, where both were applied with Bordeaux mixture. Two-

thirds of a pound of Paris green per barrel showed no material increase in effectiveness over one-third of a pound.

3. The Best Time to Spray. It has been generally conceded that the spraying just after the blossoms drop is the most important in fighting the codling moth, from the fact that two-thirds of the young caterpillars (see page 68) of the first generation enter the apples through the blossom or calyx end. The object of the first spraying is, therefore, to deposit poison in the calyx cavity, so that when the little worm enters and feeds in the cavity it is killed. It has always been recommended to spray before the calyx lobes close. Observation shows that in New Hampshire the calyces of the Baldwin apples (fully 90 per cent. of our apples are Baldwins) close about a week to 10 days after the last blossoms have dropped. In other varieties the calyx remains open longer. If the trees are sprayed after the calyx is nearly or completely closed, little or none of it gets into the calyx cavity, and the only effect from it is from that which remains on the foliage. In one orchard, where the first spraying was done after the calyces were partially closed, we secured practically no benefit from it, and correspondents who have given but one spraying ten days to two weeks after the blossoms drop have had the same experience.

Where the first spraying is given within a week after the last blossoms fall and no other spraying is given, 82 per cent. of the worminess found on unsprayed trees may be prevented; *i. e.*, if unsprayed trees had 60 per cent. of the fruit injured by worms during the whole season, trees given but one spraying would have but 11 per cent. wormy. This does not refer merely to the worminess of the picked fruit, but to the amount of both windfalls and picked fruit injured, for 11 per cent. wormy during the whole season would mean not over 5 per cent. of the picked fruit wormy.

Second Spraying. From the fact that one-third of the worms do not enter the fruit through the calyx it is evident that they cannot be killed by poison applied in the calyx cavity. As has been noted (see page 67), when the caterpillars hatch they feed a little on the foliage before entering the apple. It is evident, therefore, that by applying an arsenical spray to the foliage young caterpillars feeding upon it may be killed. Thus the spray

deposited on the foliage by spraying when the blossoms fall may kill many of the worms which do not enter the apple through the calyx.

It has usually been recommended to give a second spraying ten days to two weeks after the first one, though no very good reason for spraying at this time has ever been advanced. A second spraying at this time may be advisable for the curculio or with fungicides for various diseases, but there seems to be no reason for spraying at this time against the codling moth. It will be remembered that the eggs of the codling moth hatch about four weeks after the apple blossoms fall. Having poisoned the calyx cavities of the apples by the first spraying after the petals fall to destroy the majority of the larvæ which enter the fruit at the calyx, it would seem rational to spray the foliage where the eggs hatch to destroy the young caterpillars while they are feeding upon it. To do this the spraying would need to be done the last week in June or the first week of July. It will be seen that the time of this spraying is determined by our studies of the life history of the insect. To test the efficiency of spraying the last week in June as compared with a second spraying ten days to two weeks after the first, several plots were sprayed at each of these times and given no other spraying. Other plots were given the first spraying and then the second about the middle of June or the last week in June and these were compared. It is evident that much of the spray applied the middle of June would adhere until after the eggs hatched, but that it would probably not be as efficient as that applied just as they were hatching. Plots sprayed only the last week in June showed 70 per cent. benefit in the control of worminess as compared with 82 per cent. benefit where the first spraying only was given, showing the effectiveness of applying the poison to the foliage when the eggs are hatching. In 1907, with a normal rainfall, a plot sprayed but once, two weeks after the blossoms dropped, gave but 25 per cent. benefit, while one sprayed but once, three to four weeks after the blossoms dropped, or when the eggs were hatching, showed 47 per cent. benefit. In 1908, with but little rain in June, there was but little difference, as the poison applied earlier remained on the foliage. A second spraying given two weeks after the blossoms dropped, in addition to the first, showed

practically no increase in benefit over the first done, but when applied three to four weeks after the blossoms dropped the second spraying increases the benefit about 5 per cent.

In brief, then, our experiments show (1) that by giving but one spraying just after the blossoms fall, 82 per cent. of all the worminess during the season may be prevented; (2) that a single spraying given when the eggs are hatching the last week of June or first week of July—will prevent 70 per cent. of the worminess; and (3) that by giving both of these sprayings 85 to 95 per cent. of the total worminess may be controlled, giving not over 5 per cent. and often less than 1 per cent. of the picked fruit wormy.

It might seem that in view of the considerable injury done by the second brood that a spraying applied the middle of August to kill the larvæ of the second brood would be advantageous. Although we have made some experiments to determine this, they have shown either negative results, or have not shown sufficient benefit to make spraying at that time profitable as far as the codling moth alone is concerned. A study of our records shows that the second spraying given about July 1 lessens the injury by the second brood very materially, about one-half of its effect being due to its decreasing injury by the second brood.

However, the experience of the past two years has shown that the best way to control the brown-tail moth on apple trees is to spray them the first week in August, just as the eggs are hatching and spraying at this time for the brown-tail moth and other leaf-eating caterpillars is becoming quite general. This spraying comes at just the time the eggs for the second brood of the codling moth are being laid and comes, therefore, at just the right time to be of benefit in destroying the second brood of larvæ.

4. The Best Method of Spraying. Drenching *vs.* Mist Sprays. It has been recently recommended in the West that the first spraying be given with a high pressure and coarse, driving spray, so that it will be driven between the stamens down into the lower calyx cavity, in which cavity it is claimed that the most of the eating by the young larva is done before tunnelling into the core. Remarkable results are claimed for such spraying, in contrast to the old method, in which the finest mist was thought the most desirable and economical. Assuming the cor-

rectness of the results secured in the West, and feeling that the same methods might be equally efficient in New England, we arranged to contrast two plots given only the first spray, one in the ordinary manner with a fine mist, and the other with as high a pressure as possible, thoroughly drenching the tree with a coarse spray from Bordeaux nozzles and driving it into the calyces. Such comparisons were made in two orchards in 1907 and in three orchards in 1908. In the two in 1907 and one in 1908 the drenching spray was given with a barrel pump which could not be kept at over 80 to 100 pounds pressure. But on two of the 1908 plots the drenching was done with a gas sprayer giving 110 to 120 pounds pressure, with no material difference in the results. It is entirely evident from the large amount of data from these five plots that in New England on the Baldwins the drenching spray has no particular advantage over the mist spray, except as it may deposit more material on the foliage and apple. The reason for this is readily found by a little study of the Baldwin apple. In the West many varieties of apples have the calyx lobes still open two weeks after blossoming, and the stamen bars shrivel sufficiently to allow the passage of spray between them to the lower calyx cavity. There can be no disputing the desirability of spraying so as to deposit a spray in the lower calyx cavity, where it is so possible, but a comparison of the structure of the Baldwin apple as it grows in New Hampshire shows it to be entirely impossible, as the experiments cited corroborate. As mentioned above, the sepals usually close about one week or at most ten days after the blossoms drop. At this time the stamens are still so swollen that no spray can be forced between them, no matter how high the power or coarse the spray. If apples be examined a week or ten days after the sepals have entirely closed, the stamens will still be found turgid, as we have found by the examination of numerous specimens the present year. Such being the case, the question of a drenching, driving spray as compared with a mist spray, becomes one of climate and varieties, and which method will be most efficacious in any region cannot be dogmatically asserted until the method of growth of the apples in that region has been studied. There can be no question, however, that thorough spraying must be insisted upon. The old rule, spray until the tree commences to drip and then

stop, still seems a safe one, and to spray until there are puddles under the tree is merely a waste of labor and material under New England conditions. There can be no question, however, that spraying with a high pressure either with a barrel or power sprayer makes it possible to drive the spray into all parts of the tree and thoroughly covering the foliage, and hitting the blossoms opening inward on the far side of the tree, and will give much better results than a low pressure, even if it does not penetrate the lower calyx cavity.

5. How the Spray Kills the Larva. Various expedients were used to determine just how the larvæ are killed by the spray. If the first spraying kills them principally in the calyx cavity, then a spray applied to the calyces without touching the foliage should give nearly as good results and prove that the worms are killed in the calyx cavities. To determine this, several trees were sprayed by hand with nasal atomizers so that the spray was deposited in the calyx of each apple, but practically none was placed on the foliage. Eleven trees in three plots were thus treated and showed an average benefit of 75 per cent. as compared with an average of 82 per cent. where the first spraying alone was applied in the usual way. This proves definitely that most of the larvæ killed may be killed in the calyx and that a certain portion are killed by the poison placed on the foliage by the first spraying.

It has already been shown that by spraying when the eggs are hatching, about July 1, 70 per cent. of the worminess may be prevented. It is possible that the young larvæ may be poisoned by this spraying either by eating the foliage or by eating the poisoned surface of the apple when they enter it.

If the effect of the spray be due to the poison on the foliage only, then if the apples were covered and the foliage of the tree then sprayed there should be as much benefit as if the apples had been sprayed also. But if there is less benefit with the apples covered, it is evident that the difference in the benefit must represent the value of the spray deposited on the apples. Such an experiment was made twice. In 1907 one tree was sprayed when the eggs were hatching, after all of the apples had been covered with paper bags, which were removed immediately after the spraying. Care was taken to cover only the stems and not the nearby foliage. The vast amount of labor involved in

bagging all the apples (3,924) on even one large tree prevented a larger experiment. In 1908 four smaller trees with a light crop of fruit were similarly bagged. It is evident, therefore, that the one large tree was fully as fair a test as the four small ones. The one tree gave a benefit for the season of 52 per cent., while the four in 1908 showed only 24 per cent. benefit, the two experiments averaging 38 per cent. Thus, about half of the effect of this spraying must be due to the spray on the foliage, and the balance must be due to the spray deposited on the apples. It should be pointed out that this spray may effectually reduce the number of larvæ entering the calyx though no spray be deposited in the calyx, for we, and others, have observed that very often the larvæ eat their way through one of the sepals, rather than going to the apex and entering between them.

Further than this, any analysis of the large amount of data secured does not enable us to draw any positive conclusions as to just where or how the larvæ are killed. The general facts seem quite evident, however, that if the foliage as well as the calyces be thoroughly sprayed by one spraying just after the blossoms drop and a second three or four weeks later, that there is almost an equal chance that the larvæ may be killed by eating the foliage or surface of the apple, or by feeding in the calyx, and we would venture the opinion, which we would not attempt to prove by the statistics, though it is based upon them, that in New Hampshire on the Baldwin apple, about half of the larvæ are killed in the calyx and about half by feeding on the foliage or surface of the apple.

6. Effect of Spraying on the Proportion of Dropped and Picked Fruit. The orchard owner is chiefly interested in the effect of spraying on the amount of picked fruit free from worms. In most cases the value of spraying was due to reducing the amount of wormy windfalls, or, in other words, preventing worminess so that the fruit remained on the tree. On the unsprayed trees an average of 26 per cent. of the total fruit dropped as wormy, and 15.7 per cent. was wormy when picked.

In the four orchards sprayed in 1908, about 28 per cent. of the total fruit was wormy drops on the unsprayed trees and 5 per cent. on the sprayed trees.

An average of all the sprayed plots shows that of the total

crop of fruit on any tree, 4.7 per cent. drops as wormy and 4.1 per cent. is wormy picked.

Subtracting the percentage which drops plus the percentage which is wormy when picked from 100, gives the percentage of the total crop which is picked free from worms, which is the essential matter for the fruit grower. On the unsprayed plots the picked fruit free from worms is found to average only 43 per cent. of the total crop, while on all the sprayed plots it averages 70 per cent., a difference of 27 per cent., of the total crop. Thus a gain of about one-fourth of the crop seems to be a fair average of the actual benefit to be derived from spraying, if we base our estimates upon the total fruit borne by the tree. This would mean that on a sprayed tree which picked three bar-

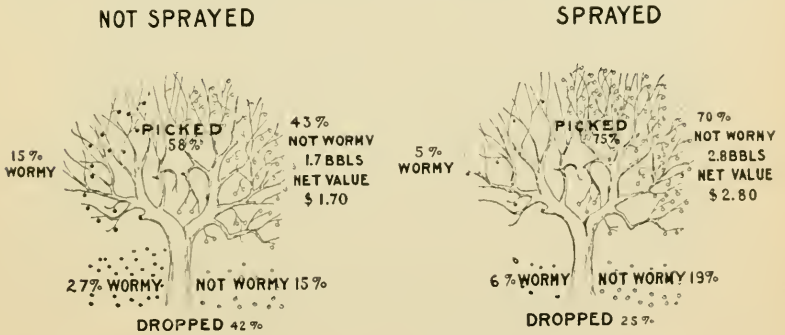


FIG. 11.— Average results of spraying in nine New Hampshire orchards in 1906, 1907 and 1908, showing the proportion of fruit which drops and is picked and the proportion which is wormy and free from worms on sprayed and unsprayed trees. The profit shown is based on a crop of three barrels picked fruit on the sprayed trees.

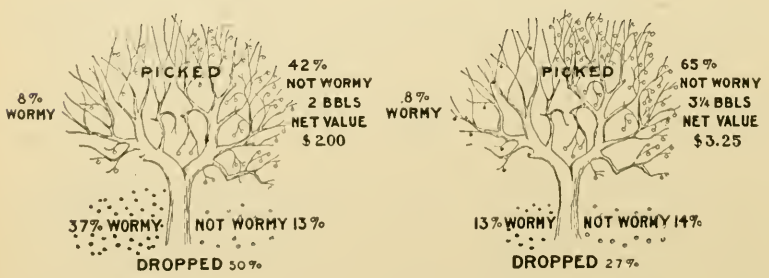
rels of fruit, one barrel of perfect fruit, worth $1 to $1.25 net, had been gained by the spraying.

If the difference in amount of perfect picked fruit was based on the picked fruit only, leaving the drops out of consideration, the benefit would appear to be only about three-fourths of that shown above, but only by taking the dropped fruit into account can a correct estimate of the value of the spraying be made. When there is an unusual amount of worminess and the best spraying, the benefit due to spraying will often amount to half of the total fruit borne by the tree, as was shown by some of our plots, which in the case of a tree with the same amount of fruit as cited above, would amount to two barrels instead of one

out of three picked being saved by spraying. But under average New Hampshire conditions, it seems a fair estimate that about one-fourth of the total fruit, or one-third of the fruit actually picked is saved as perfect fruit, by spraying. This is shown graphically in Fig. 11. Such a statement of the benefit derived from spraying is not as striking as to say that but one apple in one hundred of those picked was wormy, but the former statement merely clearly states the facts, and only one in a hundred of the picked apples may be wormy, and yet the real benefit from the spraying not be as great as on other trees, where a larger proportion of the picked fruit was wormy, but on which the spraying had prevented a large drop and thus secured a much larger crop to pick. The old saying that "nothing will lie like statistics" is well exemplified in considering the benefits of spraying as often recorded and compared.

THE CARE OF THE ORCHARD IN RELATION TO CODLING MOTH CONTROL.

The injury by the codling moth in the neglected orchard is always noticeably more severe than in one which has been given reasonably good care as regards the destruction of windfalls, pruning and scraping the trees. Although this is a matter of



general observation. in 1906 we made definite records to determine the difference in the injury in two orchards at Durham. One of these had been given practically no care for several years, and its condition was shown by the fallen limbs and the ground covered with apples, while in the other the trees had been scraped

every year, hogs had been pastured and the remaining drops had been picked up.

The diagram shows the records, kept the same as those of the sprayed trees from five trees in each orchard. In the neglected orchard one-half of the fruit dropped, three-fourths of the windfalls being wormy, while in the other only slightly over one-fourth (27 per cent.) dropped, and but half of it was wormy. In the neglected orchard 42 per cent. of the total crop of the tree was picked free from worms, making two barrels, worth $2 net, while in the orchard cared for 65 per cent. of the fruit picked

FIG. 13.— The ground covered with the droppings of the whole summer in the neglected orchard.

was not wormy, making 3¼ barrels, worth $3.25 net, and showing a benefit of $1.25 per tree at but slight cost for scraping the trees and picking up the drops, which pay for themselves in cider. Altogether the records showed that there were one-half as many wormy apples during the whole season in the orchard cared for as in the one neglected.

Usually nearly half of the windfall fruit is wormy, and the fruit drops before the worms are full grown. If it be left on the ground, the worms emerge and form their cocoons on the nearest tree. If the dropped fruit be gathered frequently, or if enough hogs run in the orchard to keep it destroyed, a large

proportion of the larvæ will be killed, and especially those which mature early and form the small second brood.

Thoroughly scraping the bark with a sharp hoe or tree-scraper, so as to remove the hiding places of the wintering larvæ will also materially aid in their control.

As has been noted, the woodpeckers and nuthatches annually save us barrels of apples by destroying the apple worms under the bark in the winter. They should therefore be encouraged and allured to the orchard whenever possible. Bits of suet and meat suspended from the trees will often attract them and sometimes help them through a hard winter.

Not only the neglected orchard but the neglected road-side and pasture trees, very many of them worthless seedlings, harbor all the pests of the apple, where they breed unmolested and constantly migrate to the orchard. Road surveyors should be required to cut every seedling or uncared for apple and wild cherry tree, and every property owner should replenish his woodpile with them.

III. DIRECTIONS FOR SPRAYING.

The following directions apply to spraying for the codling moth only. Various fungous diseases such as scab, rot, fruit spot, etc., may be controlled by spraying with fungicides and are discussed by the Station Botanist in Bulletin 144. These applications for diseases are usually combined with those for the codling moth or for other insects for which spraying may be necessary early or later in the season, but the fruit grower should know definitely against what his spraying is directed; the time for it, and what materials to use, if he is to secure the best results. The present directions, therefore, apply only to the codling moth, but the apparatus used and method of application is the same for all work in the apple orchard.

Apparatus.—The Pump. For the average New Hampshire orchard of 100 or 200 trees and farm, a good barrel pump is the best type. The small compressed air, knapsack, and bucket sprayers are good for garden work, but do not furnish sufficient pressure for large trees.

For larger orchards a horizontal, double-acting pump, used

with a 100 or 150 gallon tank, will give better pressure and will make the work more rapid. Such a pump is shown in Figure 14 and costs from $30 to $50.

For orchards of over 500 trees a power outfit will be found more economical. Gasoline engines are now most generally used for power, and are desirable in that many types may be detached from the pump and used for other purposes during the winter. Such outfits with engine, pump, tank, and tower, all mounted on a suitable truck, are sold by all the leading pump makers at from $250 to $350. Several are now in use in New Hampshire and giving excellent satisfaction. Frequently one can be used by several parties or for a whole neighborhood. One young man purchased one this year, and in a community where practically no spraying had been done before, secured enough work to pay for the outfit.

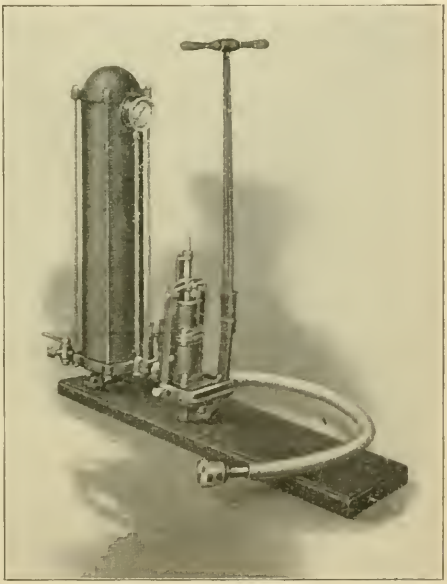


Fig. 14.— A double-acting lever pump, for use with a large tank, for large orchards.

In our own work we have used a carbonic-acid gas sprayer very satisfactorily. The outfit is shown in Figure 16. The liquid carbonic-acid gas is allowed to pass into the steel tank containing the liquid and forces it out, without the use of a pump. The operation of the outfit is simple. The expense of operation is somewhat greater than for gasoline power, but the investment is not as large and the weight on the truck is much reduced, so that a heavy horse will pull a 100 gallon tank on level ground. The gas sprayer cannot, however, be used satisfactorily with lime-sulfur mixture.

Most New Hampshire fruit growers will find the barrel pump best adapted to their needs, for by the use of a row attachment it

can be used for spraying potatoes or any other crop. Numerous requests come to us to recommend some particular pump. In reply we are accustomed to refer to the best pump companies and advise the inquirer to study their catalogs and then use his best judgment, after a careful consideration of the following points:

1. The pump should be guaranteed to furnish four nozzles at 80 to 100 pounds pressure with ordinary pumping.

2. It should have a good air chamber within the barrel, and not projecting above it as in some styles.

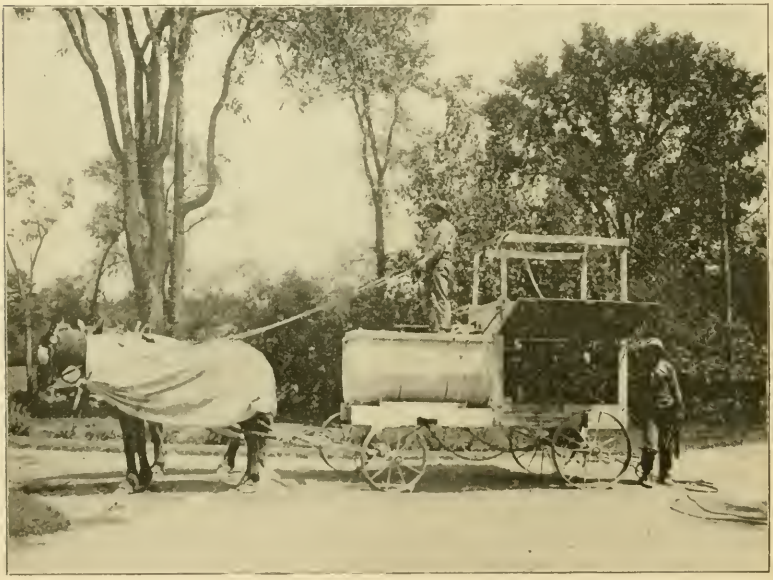


FIG. 15.— A gasoline power outfit well adapted for orchard use.

3. As few of the working parts of the pump as possible should be above the head of the barrel, as exposed parts are easily broken.

4. Pumps whose handles and other parts are made of galvanized or malleable iron are preferable to castings, which break easily.

5. The cylinder, plunger, valves and working parts should be of brass.

6. There should be a good mechanical agitator of the paddle type, preferably arranged so that it can be worked with the pump handle without operating the pump. An agitator is essential to keeping the mixture in suspension. Agitators of the so-called "jet" type, in which a stream from the bottom of the cylinder is supposed to agitate the liquid, are unsatisfactory

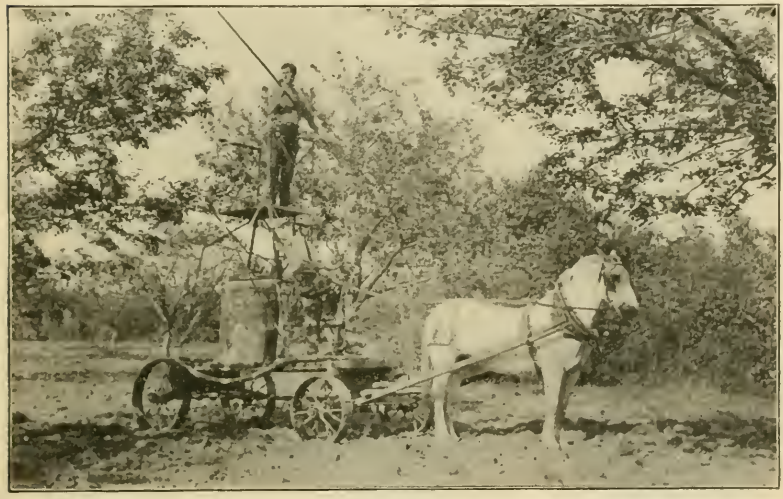


Fig. 16.— Niagara gas sprayer outfit used in experiments at Durham.

and allow a loss of pressure without sufficiently agitating the liquid.

7. The pump should be attached to the barrel so that it may be quickly removed for repairs.

8. The valves, with their seats or cages, should be readily detachable for cleaning, and should be so constructed that they will grind themselves evenly.

Possibly all of these points will not be found in any one pump, but the better pump companies, in their newer models, are adopting most of the above features. Such a pump with hose, nozzles and rod, should cost $15 to $30. A thoroughly reliable pump cannot be bought for less and if you are induced by your local dealer to buy a pump retailing for $10 or less you will soon find it unsatisfactory and give it up for a better one. A pump

embodying most of the features described is shown in Figure 17.

The following companies are making barrel pumps of the type described, and they can usually be bought through agricultural warehouses, seedsmen, etc. No mention is made in the following list of several companies making excellent pumps of other types:

The following firms have New England or New Hampshire agents, some of whom carry a certain amount of stock, while others order from the factory.

Deming Co., Salem, Ohio, represented by Chas. J. Jager Co., 281-285 Franklin Ave., Boston, Mass.

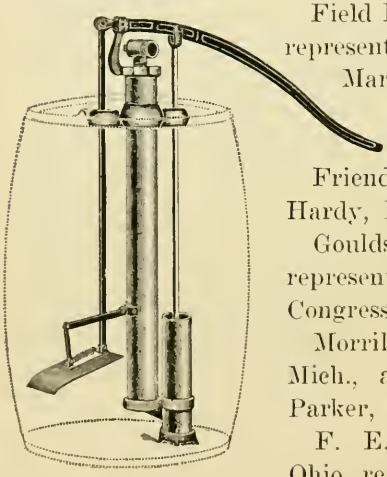


Fig. 17.—A desirable type of barrel pump, embodying most of the features described.

Field Force Pump Co., Elmira, N. Y., represented by R. & J. Farquhar, 6 So. Market St., Boston, Mass.

H. L. Frost & Co., Arlington, Mass., Douglas pumps.

Friend Mfg. Co., Gasport, N. Y., C. E. Hardy, Hollis, N. H., Agent.

Goulds Mfg. Co., Seneca Falls, N. Y., represented by Smith & Thayer Co., 236 Congress St., Boston, Mass.

Morrill & Morley, Benton Harbor, Mich., are represented by Elmer B. Parker, Wilton, N. H.

F. E. Myers & Brother, Ashland, Ohio, represented by S. B. Church Co., Boston, Mass.

Spramotor Co., of Buffalo, N. Y., represented by F. E. Fitz Mfg. & Supply Co., Boston, Mass.

Mr. A. I. Hall of Rochester, N. H., handles certain pumps manufactured by the E. C. Brown Co., Rochester, N. Y.

Others having no New England agents known to us are:—

Hardie Pump Co., Hudson, Mich.

Morris Sprayer Co., Rochester, N. Y.

Dayton Supply Co., Dayton, Ohio.

Binks Spraying Machine Co., Chicago, Ill.

Rochester Spray Pump Co., Rochester, N. Y.

The Nozzle. A good nozzle is as essential as a good pump

for proper spraying. Fair spraying may be done with a poor pump if one has a good nozzle, but it is impossible to spray with the best pump and a cheap nozzle. Many a man fails in spraying through buying some cheap nozzle which sprinkles rather than sprays. The Vermorel and Bordeaux nozzles are the types most widely used, and each have their advocates. Each are sold under various trade names, such as the Demorel and Mistry, similar to the Vermorel, and the Seneca and others the same as the Bordeaux. Usually for orchard work two or three nozzles are attached in a cluster either by a "y" tee, or ring. The lighter the nozzles and connections the better, so that some firms are now making them of aluminum, for at the end of a ten-foot rod they soon become heavy.

Recently a new type of nozzle, like that shown in Fig. 18, has come on the market and is rapidly superseding the Vermorel

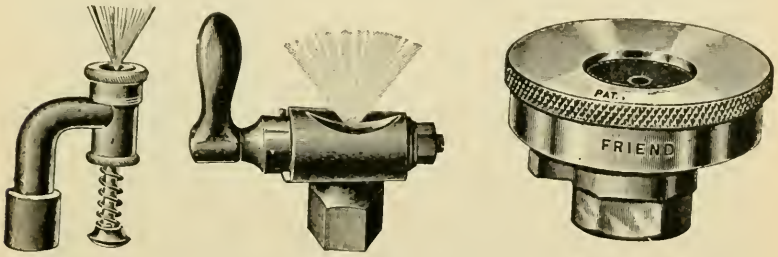


Fig. 18.— Vermorel, Bordeaux and Friend types of nozzles.

type for orchard work. This type of nozzle was originated by the Friend Mfg. Co., but is sold by all the leading manufacturers, with various modifications, under different trade names. The large flat chamber in the nozzle gives so strong a rotary motion to the spray that though there is a large aperture, a fine spray is secured. Thus all clogging is avoided. The nozzle is light and does not catch on twigs. The large opening allows the passage of a large amount of liquid, so that the work is done rapidly, one of these nozzles spraying as much liquid as two or three Vermorels. The Friend type was designed to use with a power sprayer, but will give good results with a barrel sprayer where a pressure of 85 pounds is maintained. Ordinarily one of these nozzles will be sufficient with a barrel pump, and two to a rod with power.

Whatever type of nozzle is used should be attached to the rod by a 35 degree connection, so that the nozzle points at that angle. This enables one to spray more directly over the topmost branches and under the lower ones, making the work much easier and more effective than where the nozzle is attached straight.

Extension Rod. In orchard spraying an extension rod is a necessity, especially with the tall trees usual in New Hampshire orchards. Some of these consist of a bamboo rod enclosing a light brass tube, and fitted with thread for the nozzle at the tip, and with a shut-off or stop cock at the lower end, so that the stream may be cut off when moving from tree to tree and the pressure maintained. These are light and easy to handle, but the bamboo and connections frequently break, so that many prefer using a straight piece of ⅜ or ½-inch galvanized iron pipe, threaded at one end for the nozzles and at the other for a stop cock. Wooden hand grips may be wired around the pipe, which will make it easier to hold. Ten feet is a good length.

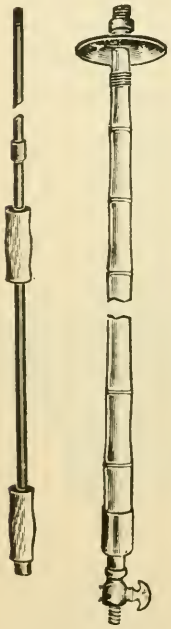


Fig. 19. — Bamboo rod with drip guard and stop cock, and iron rod with wooden hand grips.

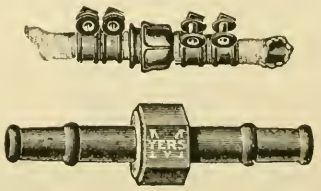


Fig. 20.— Long nipple hose coupling, and hose attached, showing double band on each side.

Hose. It is economy to get the best half-inch hose (inside measure) and to have plenty on hand. Make the joints as firm as possible, and see that the shanks to the nozzles and fittings are long enough so that the hose clamps will grip them firmly. So-called double-length couplings (Fig. 20), which permit the use of two clamps on each side of a joint, are satisfactory. A single clamp will not hold a high pressure. A few firms are offering improved hose couplings, but there is much room for their improvement. Nothing is more disagreeable than the constant breaking of couplings, with the incidental

enforced bath in the spray mixture, and many have given up spraying in despair on account of being unable to make the cheap couplings hold the hose under pressure.

Strainers. One of the most frequent causes of delay is the clogging of the nozzles from sediment, dirt, etc. To obviate this, when filling the sprayer strain all mixtures through a fine copper strainer, which may be purchased of any pump company. Have the barrel of the sprayer tight, and see that it is clean before starting.

The Wagon and Tower. Ordinarily the sprayer is simply

FIG. 21.—Wagon and tower used in the experiments; a good type for the small orchard.

placed in a wagon box in which the one spraying stands. But it is essential that the spray hit the tree from above, and it is therefore necessary that the one spraying be elevated to as near the center of the tree as possible. For any orchard of less than 500 trees, an outfit such as we have used for the past two years is entirely satisfactory. This consists of a stout one-horse wagon, on cultivated ground two horses are necessary, with a rough tower erected at the back of the wagon, which places the one

spraying on a platform about four feet above the wagon box. The platform should be as high as possible without being top-heavy, depending upon the roughness of the land, etc. Around the top of the tower is a rail to ensure the safety of the sprayer. The whole tower is readily made by anyone in a few hours from ordinary studding and rough boards, and should be firmly bolted to the wagon, so that it may be readily removable. A rough outfit of this sort used in our own work is shown in Figure 21.

Where Bordeaux mixture is used, an oiled canvas cover should be provided for the horse, extending over the head and tail and down below the shafts, as the Bordeaux mixture will injure the coat of the horse if much falls on it.

Where larger orchards are to be sprayed a truck and tower such as have come into common use in Delaware orchards, will be found more satisfactory. The tower carries two men, and the truck a 150-gallon cask, set near the ground. Two horses are necessary, and a pump of the horizontal type, like the Sentinel, Friend, etc., is preferable.

The Insecticide. To control the codling moth, we depend on arsenate of lead, or Paris green, the relative merits of which have been discussed on page 72. A few parties are using home-made arsenite of lime, but from our experience with this preparation we are not prepared to recommend it for orchard work. Arsenate of lead should be used at the rate of two or three pounds to fifty gallons of water. See that it is thoroughly dissolved before putting in the barrel.

Paris green should be applied at the rate of one-third pound to 50 gallons of liquid. We should prefer to use arsenate of lead unless Bordeaux mixture is being used and the Paris green can be used with it.

It should be noted that Bordeaux mixture is a *fungicide* used against plant diseases and has no effect whatever against the codling moth or insects. Recently considerable injury has resulted from the russetting of fruit by Bordeaux mixture, so that many have stopped using it except on varieties such as the McIntosh, upon which it is absolutely necessary to control the scab, and others are considering the use of lime-sulfur solution as a fungicide. Which arsenical will be found most satisfactory to combine with lime-sulfur is a matter to be determined by

further experiments, but the data at hand would indicate that either arsenate of lead or Paris green may be used with it in the same way as with Bordeaux mixture.

WHEN TO SPRAY.

First. Spray within a week after the blossoms fall, applying the spray so as to deposit it in the blossom end of the young apples. This must be done while the sepals or bracts of the calyx are still wide apart. This is the best time to spray for the codling moth.

Second. Spray three to four weeks after the blossoms drop, when the eggs of the codling moth are hatching. Apply this spray so as to thoroughly cover all parts of the foliage. This is a better time to give the second spraying than ten days or two weeks after blossoming.

Always give the first spraying; when possible, apply the second also; if the first spraying has been omitted, apply the second alone, but do not expect as good results from it.

We would also recommend that wherever the brown-tail moth or other leaf-eating caterpillars occur in August (See Bulletin 139) that a third spraying be given during the first ten days of August, using four pounds of arsenate of lead to the barrel of water.

HOW TO APPLY THE SPRAY.

The spray should be applied from four sides of each tree, as it is impossible to cover all parts of the tree from two points. In orchard work, drive to the interval between four trees and spray one-fourth of each, proceed to the next interval and repeat the operation, and so on. Then by coming back on the next row, the other side of one row is sprayed and each tree has been sprayed from four sides. The spraying just after the petals fall is the principal one against the apple worm, and must be directed from above the fruit with considerable force, so that the spray will be driven into the open calyces. A nozzle giving a strong spray leaving the nozzle in a good stream and making a spray with more force is therefore desirable. Nozzles attached to the extension rod so as to form an angle of 30 or 40 degrees to the rod, will be found serviceable for this spraying. Do not try to

spray against a strong wind. Spray from the windward side and wait till the wind shifts, or a calm day to spray the other side.

It is evident that it is difficult to spray either the old tree soaring skywards for thirty feet, valuable only in that it furnished a home to the friendly woodpecker, for it costs more to pick the fruit from it than it is worth, or trees scattered over a rough pasture, or following a stone wall along the roadside, where a ditch or bank often makes it impossible to reach them from the roadway. For successful spraying, as well as for proper care in culture, etc., the orchard should be in rows and the trees should be kept headed in, so that the tops can be readily reached. The day of the sky-scraper tree is passed.

COST.

The chief cost in spraying is the labor and no definite figures are therefore possible for trees scattered over a pasture, or along roadways, etc., but where they are in orchards the following figures give the actual cost in our work during the past few seasons with a barrel pump, using only arsenate of lead, amounting to a total of nine or ten cents per tree for spraying. That this price is about the average is confirmed by the growers who have reported upon it—see page 100. With a power sprayer, with good water supply and trees in solid blocks, the cost can be reduced by one-half.

Material:

Three pounds arsenate of lead per bbl., at 12c..	$0.36	
One barrel will cover 12 trees, or per tree....		$0.03

Labor:

Two men at $2 per day.....	$4.00	
One horse at $2 per day.....	2.00	
	$6.00	
Will cover 100 mature trees in 10 hrs., or per tree		.06
Total		$0.09
Additional cost for Bordeaux mixture would be		.023

CAN YOU AFFORD NOT TO SPRAY?

Profit from spraying an orchard of 100 trees:		
Average gross profit per tree, as a result of spraying for codling moth only		$125.00
Two sprayings at $0.09 each, per tree	$18.00	
20 per cent. on $35 invested in best outfit	7.00	
		25.00
Net profit		$100.00
Less cost of outfit		35.00
Net profit for first year, over 100 per cent. on investment		$65.00

Were Bordeaux also used the net profit would have been $5 less.

Can you make money more easily?

IV. CO-OPERATIVE EXPERIMENTS IN 1909.

At the request of citizens of Henniker, Derry and Chester, coöperative demonstration experiments in spraying were made at several points in each town the past season. The Station furnished the apparatus and materials and a member of its staff did the spraying. From ten to twenty trees were sprayed on each place by the Station's representative, and the owner of the orchard then used the pump for spraying the rest of his trees. One spraying was given just after the blossoms dropped with two pounds of arsenate of lead to a barrel of water. The owners of the orchards were requested to note the relative amount of dropped and picked fruit, and wormy and non-wormy fruit, on the sprayed trees as compared with those not sprayed, and report to us the commercial value of the apples secured from sprayed and unsprayed trees. These reports are as follows:—

At Henniker, J. W. Emery:

Four trees sprayed—
- Picked 77 bushels (92 per cent.)
- Dropped 6½ bushels (8 per cent.)

One tree not sprayed—
- Picked 8 bushels (57 per cent.)
- Dropped 6 bushels (43 per cent.)

(or 35 per cent. of the dropped fruit was held on the sprayed trees).

Mr. Emery writes: "I firmly believe that the spraying was successful and effective, because I never had so few drop apples as there was this season and never had the quality of fruit so good. It is practical because the expense is so small compared with the benefits derived."

Mr. S. C. Huntington, superintendent of the summer home of Judge R. M. Wallace, reports as follows:

"19 Baldwin apple trees sprayed.
Picked 70 barrels.
Dropped 1.8 bushels. Not over 5 per cent. picked fruit wormy.
2 trees unsprayed.
Picked 1.5 barrels.
Dropped 0.5 barrel; 20 per cent. wormy."

L. W. French writes: "I consider the spraying on apple trees as successful, very effective and also practical. The trees sprayed produced an average of 25 per cent. more fruit (this amount dropped from unsprayed trees) than those not sprayed, and about the same percentage more of perfect fruit was grown on the trees sprayed than on those that were not." (That is 25 per cent. more of the picked fruit was perfect on sprayed than on unsprayed trees, making a total of 50 per cent. more perfect fruit picked on sprayed trees. E. D. S.)

The orchards of A. G. and G. C. Preston were also sprayed.

R. T. Gould, Contoocook: "In 1908 we picked from my orchard about 150 barrels of apples, which sorted 90 barrels of salable mixed grade fruit, the culls being very wormy. This year, 1909, we picked 380 barrels, 335 being No. 1 grade of fine quality, 30 barrels of seconds, mostly fair but under-sized, and but 15 barrels of culls. While we have no means of knowing what the crop would have been had we not sprayed, I am thoroughly convinced that it is necessary to spray to produce our best crop of apples."

Later, November 29, Mr. Gould sent us letters from his Liverpool, England, agent, stating: "Your Baldwins showed up

splendidly, and although our market is very liberally supplied, particularly from Canada and Nova Scotia, we obtained for them absolutely the highest price of the day." And later: "The condition of your fruit was perfect, and not a single barrel was in defective condition." Mr. Gould writes: "The results obtained this year are largely due to spraying, as other apples in the neighborhood were very poor."

At Chester, N. W. Goldsmith writes: "Where I sprayed the trees I had only 5 per cent. dropped apples before October 1. Ninety-five per cent. picked from the trees were smooth and nearly all free from worms. Where the trees were not sprayed 33 per cent. dropped, all of which were wormy, and of the 67 per cent. picked from the trees, 33 per cent. were wormy or did not grow smooth. I believe that if we are to raise good fruit, smooth and free from worms, we have got to spray our trees in order to be successful. And I consider that spraying is the only effective and practical way."

A. A. Bean writes: "I know that the spraying that was done last spring was successful and effective and is what we have got to do in order to have good fruit. The apples on the trees that were sprayed were fair, smooth and nice, but on the trees that were not sprayed the fruit was wormy, gnarly, and hardly any fit for market. For example, one russet tree by the side of the road was sprayed on one side, on which the apples were nice and fair, while on the other side they were nearly all cider apples. As I have not graded the apples, I cannot give the proportions, but there will be but few twos from the sprayed trees, while on those not sprayed there will be as many twos as ones."

Orchards of W. E. Jones and A. H. Wilcomb were also sprayed and, although a decided benefit was shown, no definite figures as to the results have been obtained.

At Derry, Mr. F. M. Moore, at whose request the work in Derry and Chester was undertaken, writes as follows:

"It gives me pleasure to report to you the results of spraying my orchard here at Derry. As you undoubtedly know, we

sprayed a portion of the orchard two different times, and the results being that I have produced apples of a much nicer quality than those grown on the balance of my orchard on which no spraying was done. I find them to be of a larger size, positively free from wormholes and not affected with any blight whatsoever.

"I have also talked with and seen the fruit grown by others in Chester and Londonderry, on whose orchards spraying was done, and find the results to be the same as on my own.

"I feel very certain that those who have sprayed and given their orchards attention this year will make it a yearly practice and believe it is safe to say that most all growers in our section will see it to their advantage to spray their own orchards.

"I make it a point to buy apples every year in large quantities, and find a much better market for fruit grown on trees that have been sprayed (even at an advance of 50 cents to a $1 a barrel) from that grown on trees that receive no care.

"Will say as regards drop apples that there was a very small percentage when compared with those from trees not sprayed.

"I feel that we are on the road to produce better fruit and more of it in our section.

"As per our agreement I enclose you record from my orchard: Twelve sprayed trees, picked 49 barrels apples. Packing 43 barrels (80 per cent.) No. 1s, 5 barrels No. 2s, 1 barrel cider. Drops from 12 sprayed trees, 6 barrels (11 per cent.), of which 2 sold for No. 2 drops and 4 sold for ciders.

"Twelve trees not sprayed. Picked 22 bbls. (65 per cent.) apples. Packing 16 bbls. (47 per cent. No. 1s), 5 bbls. No. 2s, 1 bbl. ciders. Drops from 12 trees not sprayed, 15 bbls. (35 per cent.), of which 5 sold for drops and 10 sold for ciders.

"(Signed) F. M. Moore."

V. PROGRESS IN SPRAYING IN NEW HAMPSHIRE.

In Bulletin 131 in April we made the statement, "There are probably not a score of men who spray regularly and intelligently in New Hampshire." Recent investigations have shown this statement to have been practically true. During the past two years there has been an enormous increase in spraying in New Hampshire, and we have thought it worth while to deter-

mine just how generally it is being carried on and what results are being secured.

In the early fall a reply postal card was sent to the chairman of the selectmen in each town and to the master of every grange in the state, asking the names of those who sprayed in their section. Out of 235 towns reports have been received from 111, in

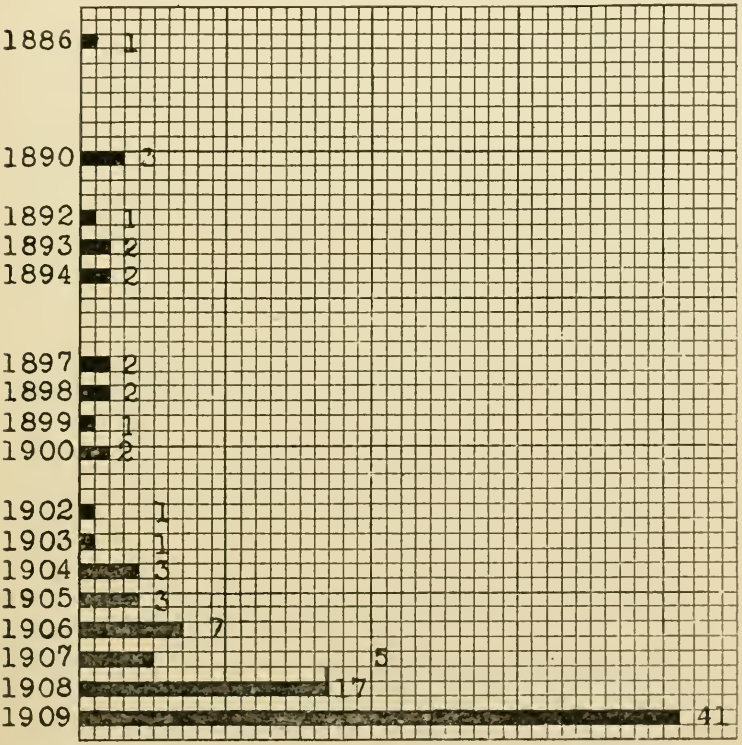


FIG. 22.— Diagram showing the increase of spraying in New Hampshire as reported by 96 individuals. The black areas represent the number who commenced spraying in the year named, each square representing one individual, and not the total number spraying that year. As the diagram is based on nearly 100 reports the numbers commencing each year may fairly be considered as giving the percentage of spraying in the whole state which commenced for each year given.

71 of which are one or more parties who spray and in 40 of which no spraying is done. The distribution of those spraying is shown in the map, Figure 23. As Coös County grows but about 1 per cent. of the fruit produced by the state, Sullivan County 5 per cent., and Belknap and Carroll Counties each 6

per cent., it is not surprising that practically no spraying is reported from them. The map shows that spraying is more general in the leading fruit growing sections of the state and where a few growers have been spraying for some time.

In the 111 towns there were reported the names of 345 parties who sprayed. To each of these a letter was sent requesting a reply to the following questions:

1. In what year did you first spray?
2. How many bearing trees do you spray on your own place?
3. Do you spray for neighbors? If so, give their names and number bearing trees sprayed for each.
4. Against what insects or diseases do you spray particularly?
5. How many times during the year do you spray? Give approximate dates.
6. What insecticides and fungicides do you use and at what strength?
7. What sprayer do you use?
8. What does it cost you to spray? Total, or per tree.
9. How much profit per tree do you think you receive from spraying?
10. If you can compare sprayed with unsprayed trees, what difference have you observed as to quantity and quality of picked fruit?

At this writing, December 20, one hundred replies have been received, which is a very large proportion to secure for such a questionaire, especially as no reply envelope was sent, and which number enables us to determine a fair average.

The replies to the questions have been carefully studied and are summarized as follows:

1. The year in which spraying was commenced was given by 96 parties and is shown graphically in Figure 22. This shows that over 60 per cent. sprayed for the first time in 1908 and 1909. Furthermore, those who are reported as spraying prior to 1900 usually state that they sprayed but irregularly, mostly for the canker worm.

2. Ninety-five reports give an aggregate of 22,305 apple trees

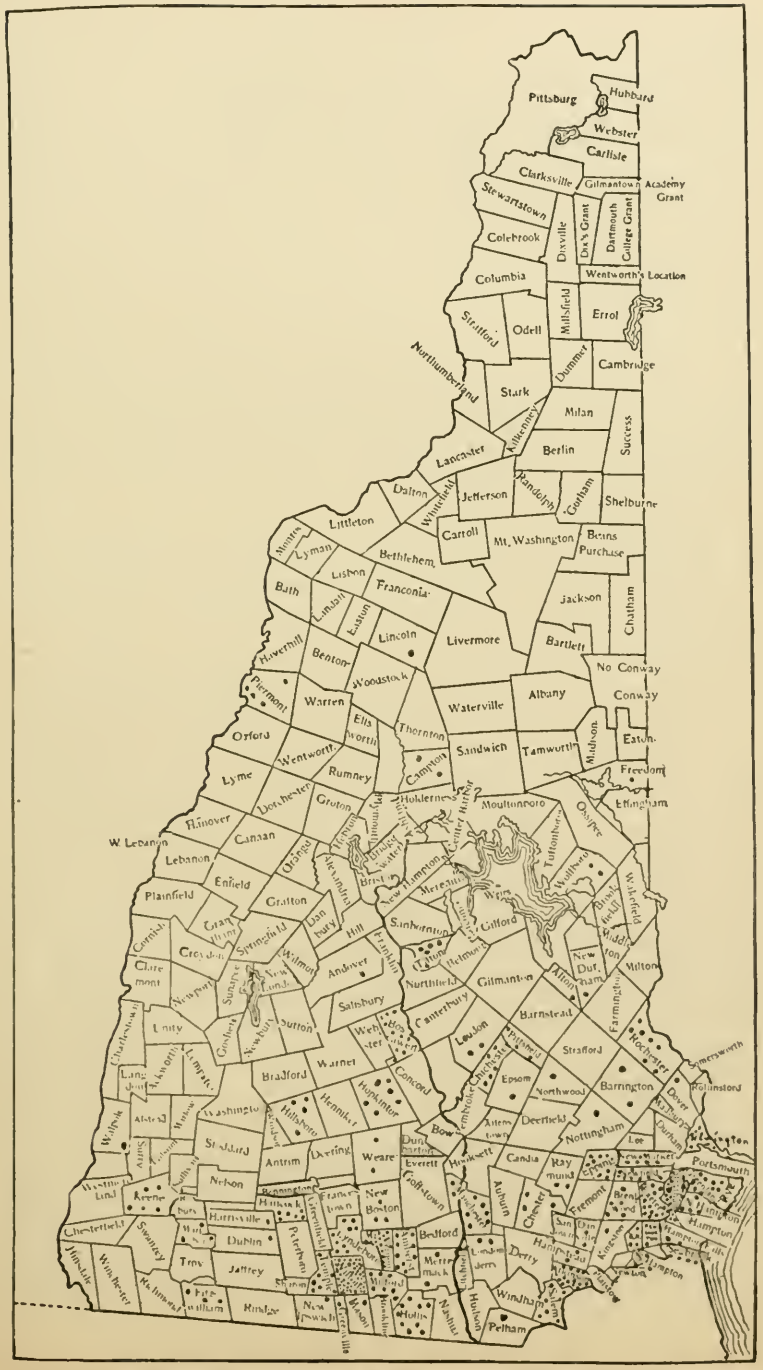


FIG. 23. — Distribution of spraying in New Hampshire. Each dot represents one party reported as spraying.

sprayed, averaging 235 per farm, excluding several large peach orchards.

3. Twenty-seven parties sprayed 6,102 trees in 75 orchards for neighbors, averaging 81 trees per orchard.

4. Practically all spray against the codling moth, giving one or two sprayings in June. About one-third spray against the brown-tail moth in August. Seventy per cent. spray also for fungous diseases. A few spray for various other insects, particularly San José scale, as occasion arises.

5. Out of 90 reporting, 48 per cent. spray but once, when the blossoms drop; 35 per cent. spray twice, 10 per cent. three times, 5 per cent. four times and 1 per cent. five times.

6. Of 94 reporting, 65 per cent. use arsenate of lead and 10 per cent. use Paris green. Twenty-six per cent. use a manufactured combination insecticide and fungicide, consisting of arsenate of lead and Bordeaux paste, while 45 per cent. use home-made Bordeaux mixture applied with arsenate of lead or Paris green.

7. Nearly all use barrel pumps. Ten per cent. have their spraying done. Two per cent. use knapsack or bucket sprayers. Three per cent. use horizontal, double-action pumps of the Sentinel type. One has a gas sprayer and three report gasoline spraying outfits.

8. Fifty-four parties give fairly definite figures as to cost, which runs from 5 to 30 cents per tree, averaging 10 cents.

9. But few were able to answer as to the profit received per tree, as they had not considered this or made direct observations upon it. Thirty-two parties give sufficiently definite figures either as so much cash benefit per tree or in terms reduceable to the same basis. These reported all the way from 75 cents to 10 dollars per tree profit, and average $2.50 per tree. Many reported the benefit in proportion of number one and number two fruit on sprayed and unsprayed trees, which amounted to an average difference of 40 per cent. No. 1 fruit more on the sprayed trees. With three barrels of fruit per tree, at $2 per barrel, this would amount to $2.40, or practically the same as given above. Five per cent. of the picked fruit was imperfect on the sprayed trees. Further comparisons as to the benefit are given below.

After a study of these replies we were interested to make an estimate of just how much profit those New Hampshire fruit growers who have sprayed the last season have secured by it. Ninety-five reporting had 22,305 trees. If two-thirds of these bore fruit (usually only those bearing are sprayed), there would have been 14,870 sprayed, which at a profit of $2.50 per tree, would give $37.425 profit; 6,102 trees for 75 neighbors were also

sprayed, and if two-thirds bore, with the same profit per tree, these would show a profit of $10,000. Two hundred and fifty parties are known to spray from whom we received no reports, from which 25 may be deducted as being among those hiring their spraying done. It is probable that these growers failing to report have fewer trees and receive less profit, so to be conservative let us credit them with 150 trees each (the average for the state is 70 trees per farm), and that they secured $2 profit per tree on two-thirds of the trees which bore. This would give 22,160 trees bearing, or $44,320 profit. Thus the 345 parties who are known probably sprayed 61,657 trees in 1909 securing a total profit of $81,755, on about 100,000 barrels of apples, representing a fourth of the crop[1] produced in New Hampshire in 1909. This profit is possibly somewhat higher than it would be most years, as apples sold from $3.25 per barrel at Boston October 25, 1909, while for the last 20 years they have averaged $1.90 to $3.25 on the same date; thus, $1.50 per barrel on the tree is probably a fair average price, and were the above profits computed on that basis, they would have amounted to $61,695.

In 1899 there were approximately 2,000,000 apple trees in New Hampshire. Only half of these, or 1,000,000, bear each year, and probably not over one-third of these bear first-class crops, or 300,000. But if these were all sprayed, we would have an annual profit of $450,000 due to spraying alone. This would mean spraying 15 per cent. of the trees in the state, or five times as many as were sprayed in 1909,—61,657, or 3 per cent. Such a benefit will undoubtedly be secured from spraying within the next five years, judging from the remarkable increase in it during the last three years.

This Station commenced a definite campaign for spraying in 1905 and Bulletin 131 was published in April, 1907. The increase in spraying is by no means all or mostly due to the work of this Station, as manufacturers and agents of spray pumps and insecticides have shown the people its value. Speakers and exhibits at our State Horticultural Society have shown its value, and, most important of all, the growers who have sprayed have shown such results as to convince their neighbors. But it may be fairly claimed that the work of this Station has furnished at least the primary impetus to which the greatly increased amount of spraying in 1908 and 1909 was due.

We were interested, therefore, to determine just what profit had been derived by those who have sprayed only in 1908 and 1909. In 1909 these formed 60 per cent. of those spraying, so that 60 per cent. of the previously computed profit, or $49,053,

[1] The New England Homestead estimates 400,000 barrels for New Hampshire in 1909—certainly a generous estimate.

was secured by them in 1909. In 1908 but 17 of the 96 reporting sprayed for the first time, and if we consider the same proportion for the 245 unreported we have 62 parties with 10,945 trees. If two-thirds of these bore fruit with a profit of $1.50 per tree from spraying, there was a profit of $10,945 in 1908 to those who had never sprayed before. Adding this to that secured in 1909 makes a total of $60,000 profit secured by spraying in 1908 and 1909 by those who had not previously sprayed. The total cost of the investigations of this Station, paid from the Station funds appropriated by Congress, from July, 1905, to January 1, 1909, amounted to about $5,000. So that the profit received by New Hampshire fruit growers who sprayed for the first time in 1908 would have paid the cost of these investigations twice and in 1909 ten times. Such work seems expensive from the standpoint of the individual, but when the aggregate value of the crop and the actual increased production secured is considered, seemingly costly investigations prove themselves to be cheap and the best possible investments.

VI. REPORTS ON EFFECT OF SPRAYING.

George E. Gowen, Stratham, N. H., 500 trees. Has sprayed since 1900. "When I spray I get good apples. Trees not sprayed are very poor. The sprayed apples are much better by 4 to 1."

A. R. Marsh, Stratham, N. H., 100 trees. Sprayed irregularly for 10 years, regularly for 3 years. "In a year like this, spraying means the difference between having apples and not having them, as a great deal of the fruit was scattering and must have fallen but for spraying. I hate to touch an apple or an orchard that has not been sprayed since handling sprayed fruit, and the trees sprayed seem to have a bulldog grip on the apples, so the loss from windfalls is small."

Otis R. Connor, E. Andover, N. H., 400 trees. Has sprayed since 1893. As to profit per tree from spraying, he writes: "Never figured it out, but one year the whole crop of 400 to 500 barrels. There is a difference of one-half in No. 1 fruit."

George F. Badger, Wilton, N. H., 1,200 trees. Sprayed first in 1909. "My fruit was never better. I think the spraying did it. I find the sprayed fruit much better, and the apples hang on a great deal better where sprayed."

Daniel W. Ladd, Epping, N. H., 600 trees. Sprayed first in 1904. As to the profit secured by spraying, he rates it at "100 per cent., and I am not sure but I got 200 per cent. The sprayed fruit is twice as large, perfectly smooth and free from scab or worm holes and the trees are more healthy."

C. A. Jenkins, Milford, N. H., 100 trees. Sprayed first in 1909. As to profit per tree, he states: "Judging the present and the past, I received more than $100 net per tree."

Frank A. Hardy, Derry, N. H., 500 trees. Sprayed first in 1907. "The sprayed tree fruit was first class. Unsprayed fruit was wholly unfit for market."

Augustus A. Melendy, Wilton, N. H., 500 apple, 600 peach trees. Sprayed first in 1908. As to the profit per tree from spraying, he writes: "If a tree should bear 6 or 8 barrels of poor, scaly fruit covered with fungus and not salable and by spraying they grew large and smooth and sold for $3.00, as mine did this year, you can tell for yourself the profit. Formerly my apples were small, wormy and with some fungus. This year my apples were very large, smooth, and not one speck of fungus did I find on the 800 barrels."

A. W. Clough, Greeland, N. H. Sprayed first in 1908. Sprays for numerous parties aggregating 1,200 trees. As to the profit per tree from spraying, he writes: "$1.25 in the last two years. On some trees $6.00. There should be $4.00 profit on all mature trees here (on his own place) when I get them in proper condition." As to the difference observed in sprayed fruit, he writes: "I have noticed that by spraying we check the inroads of diseases and insects, and thus the tree has more vigor to retain its fruit during the summer and late fall. Thus we get the naturally fine product of a healthy tree. We secure 50 per cent. more in quantity and 75 per cent. more in quality on sprayed over unsprayed trees."

Fred Jones, Wilton, N. H., 150 trees. Sprayed first in 1909. "My sprayed fruit ran 90 per cent. No. 1 fruit, and where I did not spray it was only 25 per cent. No. 1. This has been my first experience in spraying, and I only sprayed one-half of my bearing trees this year, but I am satisfied if I had sprayed them all it would have paid me, as I had over 700 barrels. Shall spray them all next year."

Austin Holt, Wilton, N. H., 300 trees. Sprayed first in 1908. "On unsprayed trees the apples ran 3 good to 1 poor fruit. On sprayed trees they ran 10 good to 1 poor."

George H. Folsom, Penacook, N. H., 300 trees. Sprayed first in 1908. As to the amount of profit per tree from spraying he writes: "It is hard telling. Worth $150 sure and I think much more on my whole place. On trees bearing seven barrels of fruit it was worth $3.00 per tree. On the unsprayed trees the foliage is inferior and the apples dropped badly. The fruit was worth double where sprayed and I got 50 per cent. more apples. I would be ashamed to say that I was in the fruit business and did not spray my trees. It would be like showing a

field of corn that I had neglected to hoe and was overrun with weeds."

William Clark, Londonderry, N. H. "The results have been very satisfactory. The material remained on the leaves of the trees till they fell in the fall. No insects that feed upon the leaves could live on them. I had practically no wormy apples. The quantity of fruit was increased and the quality has been good in every way except size. I got too many apples. (This must be overcome by thinning.—E. D. S.)

Rev. F. Pearson, Hancock, N. H., 600 trees. Sprayed 100; first in 1909. "Shall have a much larger proportion of perfect apples, not over 5 per cent. wormy. A few trees sprayed had perhaps 20 per cent. wormy, but a few next the woods unsprayed were 90 per cent. wormy."

Robert T. Gould, Contoocook, N. H., 150 trees. "I think that spraying increases the value of the fruit several hundred dollars. On my own farm sprayed trees had not more than 10 per cent. wormy apples, while unsprayed trees had nearly or quite 50 per cent. wormy apples."

E. G. Flanders, Brentwood, N. H., 50 trees. Sprayed first in 1909. "Had but very little fruit last year, but the quality is very much improved. Secured perfect Flemish Beauty pears where I never had one before."

George W. Phillips, W. Concord, N. H., 225 trees. Sprayed first in 1899. On unsprayed trees half the apples are No. 2s; on sprayed trees not over one-third. The amount of No. 2 fruit is decreasing from year to year. "As to the benefit, 500 barrels of apples unsprayed would average 50 per cent. No. 2; sprayed would average one-third No. 2, therefore spraying which cost me $12.50 gives me 17 per cent. more No. 1 apples at a market price of one dollar per barrel, or in other words I get $85 for an outlay of $12.50 on my apples alone. I am satisfied that spraying pays the best of any work done on the farm."

H. T. Taplin, Newfields, N. H., 150 trees. Sprayed first in 1908. "I sprayed only once in 1908 just after the trees shed their blossoms. As a result I had some of the finest apples ever raised in this section. I left a few trees unsprayed and the difference in the fruit was very great."

Elmer B. Parker, Wilton, N. H., 200 apple, 1,200 peach and 900 young trees. Sprayed first in 1898. "If my fruit if unsprayed were all like that on one I left unsprayed this year and like that of some of our growers who did not spray, I should call the profit the difference between a crop of all No. 2 and a crop seven-eighths of which is No. 1. I find the difference so noticeable that everybody speaks of it in favor of the sprayed fruit."

Joseph E. Fowle, Amherst, N. H., 150 trees. Sprayed first in 1909. "They ran 70 per cent. No. 1s; for the last two or three years we have not had any No. 1s. Unsprayed trees had two-thirds seconds and were very small, dropped badly compared with the sprayed trees."

W. H. Batchelder, Stratham, N. H., 30 trees. Sprayed first in 1909. "Had four trees side by side with about equal bloom. Two unsprayed yielded one-half bushel wormy and one peck of good apples. The two sprayed trees gave 2¼ barrels of market fruit and one peck wormy, gnarled and small. This is my first experience, and I am unable to give exact figures as to cost, but figure that one day's work on 30 trees paid me at least $60.00 net profit."

S. T. Worthen, Manchester, N. H., 800 trees at Mount Vernon. Sprayed first in 1905. Estimates the profit per tree from spraying at $10.00. States that he secures 90 per cent. better fruit on the sprayed trees. Mr. Worthen sprays five times, commencing when the blossoms fall and then every ten days until the first of August, and has fruit of remarkably fine quality.

Roscoe T. Harden, Portsmouth, N. H., 27 trees. Sprayed first in 1907. As to profit per tree, he writes: "In 1907 about $2.00 per tree, 1908 about 75 cents per tree, 1909 about $2.20 per tree. I tried spraying one year and got about twice the quantity and 75 per cent. better quality on sprayed trees over the unsprayed compared with good bearing years."

E. S. Walker, Alton, N. H., 40 trees. Sprayed first in 1906. As to the value from spraying, he writes: "With six trees not bearing I have 34 trees, from which we secured $150 to $175 worth fruit this year. The total labor, cost of packing, carting and the barrels cost $45 or $50 at the outside. If I had not sprayed I would have gotten about $20 worth of fruit. Last year, 1908, I got only $10 worth of fruit, and the bloom was heavier than this year, as they were all wormy and rotted heavily. I presume the 34 trees netted $100, or $3 per tree."

James C. Piper, Stratham, N. H., 300 trees. Sprayed first in 1892. "Where we have sprayed we find nearly all the fruit remains on the tree and is almost entirely free from worms, and of much better quality."

Fred C. Gowing, Dublin, N. H., 250 trees. Sprayed first in 1894. Estimates his profit from spraying in 1908 at $300 to $400 and in 1909 $100 to $200. "We get quite a lot more fruit and better quality. Buyers will generally give more for my fruit, and I get a better price on the foreign market. Trees should be well pruned and well manured. As sprayed trees will set a heavier crop, a farmer that has apple trees can do no other work so profitable as spraying."

A. I. Hall, Rochester, N. H., 2,000 trees. Sprayed first about 1886. Estimates his profit from spraying at about $1 a barrel on the fruit, which would mean as high as $8 per tree on some trees. In some cases the sprayed trees have had all No. 1 fruit and the unsprayed trees all No. 2, that is on McIntosh and Snow or Fameuse trees.

C. M. de Rochemont, Portsmouth, N. H., 175 trees. Sprayed first about 1890. Now uses a power sprayer. As to the profit per tree, he writes: "I believe I received ten dollars for every dollar expended in spraying."

John T. Moore, Boscawen, N. H., 2,500 trees. Sprayed first in 1907. In 1907 about 5 per cent. of the crop affected with codling moth, as against 75 per cent. in previous years. In 1909 about 7 per cent. affected with codling moth due to windy weather during spraying. "In this section spraying saves fully 33 to 75 per cent. of the crop and improves the entire crop. The apples seem to mature better and are more uniform in size and color than in unsprayed orchards. Outside of sprayed orchards, there was little marketable fruit in this section this year, and several more will spray next year."

THE EFFECT OF SPRAYING ON THE BROWN-TAIL MOTH.

A. R. Marsh, Stratham, N. H., writes: "We have captured the brown-tails for two years where we sprayed once with arsenate of lead for the codling moth. Last year we sprayed only those trees that blossomed, and when we came to harvest the brown-tail moth nests in early winter there were but two or three nests per tree, while trees nearby were well covered, and this year, with the whole orchard sprayed, after the fall of the blossoms, we have destroyed them all except for a few scattering ones where we did not hit the foliage."

Frank A. Hardy, Derry, N. H.: "This year I sprayed a few young trees in the month of August and killed every caterpillar there was, and now there is not a nest on the trees that were sprayed in August."